ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

PROJECT NO. 7 - NIGHT VISION FROM TANKS

First Partial Report

On

Sub-Project No. 7-1, Determination of the Lighting Requirements for Various Tasks of Tank Crews

Project No. 7-1

INFORMATION COPY

5 August 1943

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741-12 GNOML

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1. PROJECT: No. 7 - Night Vision From Tanks. First Partial Report on Sub-Project No. 7-1, Determination of the Lighting Requirements for Various Tasks of Tank Crews.

a. Authority - Letter Commanding General, Headquarters Armored Force, Fort Knox, Kentucky, File 400.112/6 GNOHD, dated September 24, 1942.

b. Purpose - To develop, in a usable form, the requirements for interior tank lighting arising from a consideration of the factors which determine efficiency of crew vision under day and night operating conditions.

2. DISCUSSION:

In order that tank crew members may carry out their tasks effectively, it is obvious that they must be able to see efficiently. Effective vision, although conditioned by other factors such as outside illumination, is largely dependent upon the illumination within the tank which, in turn, is determined by design and location of fixtures, candlepower of bulbs and range of control of light intensity. In this report an attempt is made to evaluate the relationship between these factors and resulting crew vision for both day and night operating conditions, and thus to determine the basic requirements for interior tank lighting. Details of tests and further discussion of the problem are presented in Appendix I.

3. CONCLUSIONS:

a. A dual lighting system, supplying at each crew position white light for daylight operation and red light for night operation, both controllable as to intensity throughout the proper range, is required to provide the amount and type of illumination necessary for efficient vision during day and night operations.

b. A six candlepower bulb in an efficient reflecting fixture provides adequate illumination (up to 10 footcandles) to meet the maximum demands for daytime illumination at any selected position, insuring a reasonably short glare recovery time after eye exposure through a periscope or other vision device to bright outside light.

c. A six candlepower bulb in an efficient reflecting fixture, fitted with a red filter of transmission characteristics of DA Navy goggle material, provides usable illumination up to 1 footcandle, which is ample light for all night operations. When supplied with a rheostat or other control device, the intensity of illumination can be set for the task at

hand and thus insure optimum preservation of dark adaptation.

d. The distribution of light provided by 6 cp bulbs in the fixtures now employed in tanks is satisfactory.

e. The location of light fixtures should be selected with reference to the requirements of the visual tasks at each crew position and the relative amount of light required for the efficient performance of each task.

f. Light fixtures should be so located that they do not, themselves, constitute sources of glare or produce disturbing glare by shining directly into periscope windows or onto other specular reflecting surfaces.

g. Light fixtures and controls should be located for accessibility and convenient operation.

4. RECOMMENDATION:

That this report be distributed to agencies concerned with design of interior lighting systems for tanks and other armored vehicles.

NOTE: This report provides basic information on the principles of design of interior lighting systems. It is supplemental to the report on Project 7 - Night Vision From Tanks, Sub-Project No. 7-2 - Determination of Intensity, Distribution and Type of Illumination in Tanks Least Disturbing to Dark Adaptation. Sub-Project No. 7-3 - Investigation of Methods of Improving Night Vision in Tank Crews by the Use of Eye Appliances, entitled Report on Interior Lighting of M4 Tanks, 25 February 1943, and is applicable to the problem of interior lighting of all armored vehicles which are intended for use at night.

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#1 - Appendix
#2 - Table 1
#3 - Figs. A, B, &C

APPENDIX

Lighting Requirements

For the efficient performance of the various tasks which tank crews must perform, certain minimum amounts of light are required. Among the duties of the crew, map reading undoubtedly requires the highest level of illumination. The amount of light necessary for the location and identification of stowage items, on the other hand, is probably the lowest. For a given task the illumination required varies with conditions inside and outside the tank. In the daytime, for example, crew members are required to look out through the periscopes or other visual devices in order to drive the tank, spot the enemy, sight targets, etc. Alternating with this, they must manipulate the controls, load weapons, clear the machine guns, read maps and perform other tasks inside the tank. Thus, the crew members' eyes are exposed alternately to outside and inside light levels, which at times may differ as much as a thousandfold. When this difference in intensity is great, glare results from exposure to the outside illumination and a certain period of time is required for the eyes to become adjusted to the lower light levels inside the tank. During this period of adjustment, visual efficiency is greatly reduced with a corresponding reduction in ability to perform the task at hand. For daylight operations, therefore, with high levels of outside illumination, it is necessary to provide relatively bright light inside the tank in order to keep at a minimum the so-called "glare-recovery" time.

At night, in contrast to daytime operations, only the minimum illumination is required for efficient performance of the necessary tasks since there are no disturbing sources of outside glare and the eyes are adapted to low light levels. Furthermore, in order to preserve dark adaptation during night operations, illumination should be by red rather than white light.*

As a basis for design of the interior lighting system of a tank or other armored vehicle, the various tasks of each member of the crew should be carefully appraised with respect to illumination requirements. Once these have been established, it is a relatively simple matter to select the proper location of the fixtures and to determine the bulb requirements to meet the necessary illumination specifications.

The illumination requirements for various tasks within the tank were studied by performing the actual operations or closely simulated work at various known light levels. In the course of this work it became evident that definite levels of required illumination could not be established unless such factors as tank motion, degree of dark adaptation, individual variations in visual acuity and others, were taken into consideration. It was possible, however, to select certain maximum values for each of the most important tasks which would allow for the effect of these variables. Assum-

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* The use of red light and low levels of illumination at night have the added advantage of minimizing enemy detection of the vehicle by light leakage thru periscopes and other apertures.

ing that the intensity of illumination within the vehicle can be controlled by rheostat or other means, it is obvious that with a lighting system having sufficient capacity to develop the illumination necessary for the most difficult tasks under conditions of maximum severity, all lower values will be readily obtainable.

As a basis for determining the maximum illumination requirement for daytime operations, it was essential to determine the relation between glare-recovery time and illumination within the tank for various levels of outside light. This relationship was determined as follows: The time, in seconds, required for the adjustment of the eyes so as to permit the performance of a set visual task was determined for each of 5 men after 5 minutes of eye exposure to a glare source viewed through a standard tank periscope. Observations were made upon each man with various fixed levels of outside illumination in combination with different intensities of interior illumination representative of the practical ranges of lighting obtainable in tanks. The outside illumination levels were selected to cover the range of daylight, up to an extreme value of 10,000 footcandles, which represents the illumination produced by bright sunshine on snow or white sand at latitudes near the equator. The set visual task employed in these tests consisted in the easy reading of the relatively fine print in the Saturday Evening Post. Preliminary tests had demonstrated that the visual requirements for this task correspond well to the requirements for the reading of maps of the type generally carried in tanks. The outside glare source was obtained by the uniform illumination by means of mazda flood lamps of white paper having low specular reflection. The results of these tests, based upon data obtained with the 5 subjects, are shown in the form of a family of curves in Fig. A.* It will be noted that for a given recovery time the relation between interior and outside illumination changes rapidly when the level of interior lighting is relatively low. One notes, also, that the improvement in recovery time is not marked with increases in interior illumination beyond 10 footcandles. Under the extreme conditions of 10,000 footcandles, outside illumination, and 10 footcandles inside the tank, a recovery time of approximately 5 seconds is required.

For night operations the requirements for red light illumination were studied in relation to such variables as the degree of dark adaptation. For the performance of the most difficult tasks, as map reading, and with eyes adapted to dark, the red light illumination required was found not to exceed 1 footcandle.

As a result of these tests and in consideration of the variables which influence the lighting requirements, the maximum levels of illumination necessary for the efficient performance of various tasks within the tank

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* An empirical relationship between I_i, Interior light level; I_o, Outside illumination and t, recovery time in seconds, may be expressed by the following equation:

$$I_i = 0.65e^{\left(\frac{2.9}{t^{1.41}} \times \frac{I_o - 600}{1000}\right)}$$

Mel. #1

throughout the range of day and night operations have been established and are tabulated in Table 1.

Lighting Fixtures

It is not necessary to illuminate the entire interior of the tank uniformly provided that each crew member has adequate light so that he can perform efficiently all of his tasks without having to grope about, and without excessive eye strain. Knowing the desired light levels in each working area and the relative amount of light required for the efficient performance of each task, the design of an interior lighting system becomes simply one of providing lighting fixtures of the required capacity and determining the number and location of the fixtures to meet the needs of each crew member.

With regard to the capacity of each fixture the lighting requirements given in Table 1 may be employed as a basis of evaluation. Using these criteria, the performance of the lighting fixtures now employed in tanks was studied. Light distribution curves for the standard fixture equipped with a 6 cp bulb are shown, for white light in Fig. B, and for red light in Fig. C. It will be observed from the distribution curve for white light in Fig. B, that the maximum desired illumination of 10 footcandles is developed over a very narrow area, directly under the fixture and within a distance of less than 1 foot. At the 1 foot level, an intensity of illumination exceeding 5 footcandles is produced over a circular area slightly over 1 foot in diameter, while the outer ring 2 feet in diameter has an illumination of somewhat more than 1 footcandle. It is evident from this that the present fixture does not quite meet the maximum requirement of 10 footcandles for use under the extreme outside conditions of 10,000 footcandles. It may be pointed out, however, that this extreme condition is not a common occurrence. Furthermore, there is a rapid decrease in the required level of interior lighting for a glare-recovery time of 5 seconds with decreasing values of outside light below 10,000 footcandles (See Fig. A). From a consideration of the foregoing, it is concluded that the 6 cp bulb in the standard fixture now employed is adequate to meet the light requirements for daytime operations. For night operations with red light the fixture is also acceptable. The distribution curves in Fig. C show that with a proper red filter, a level of illumination in excess of 1 footcandle is produced at a distance of 1 foot directly under the fixture.

The number and proper location of lighting fixtures in a given vehicle can be determined only by the actual installation of fixtures in various positions and measuring the resulting light distribution in relationship to the working area for each crew member. The recommended number and location of fixtures for the M4 tank, given in a previous report,* were determined in this manner. For the determination of fixture

* Report on Interior Lighting of M4 Tanks, Projects No. 7-2, 7-3, February 25, 1943.

locations in any other vehicle a similar procedure should be followed. Other important factors which must be considered in the final selection of number and location of fixtures are: accessibility of the lights and convenient operation of switches and other controls, and the absence of glare from the fixture itself or indirectly in the form of reflection from periscope windows or other specular reflecting surfaces.

Control of Illumination Intensity

Means for decreasing the intensity of illumination at each crew position is an essential feature of the lighting system since the capacity of each fixture, as pointed out above, is determined by the maximum lighting requirements. Rheostats or other suitable control devices must, therefore, be provided for in the design of the system. If control of intensity is accomplished by means of rheostats they should be capable of withstanding to a reasonable degree, the road and impact shocks to which they are to be subjected.

Incl. #1

TABLE I

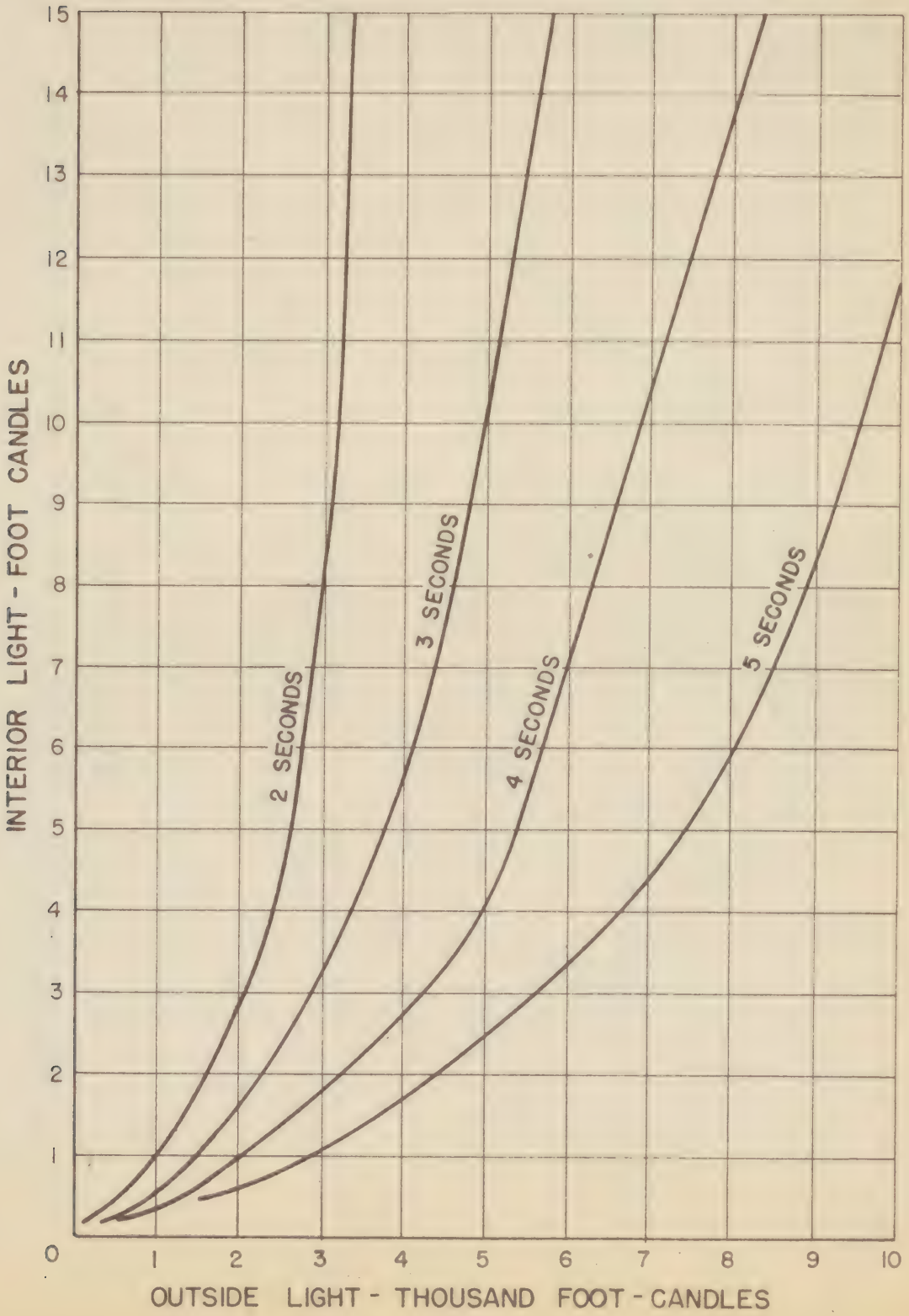
Levels of Illumination for Efficient Performance
of Various Tasks in Tanks

	Night Operation (Red Light)	Daylight Operation
	Footcandles	Footcandles
Map Reading	1	10
Clearing MG	.4	4
Operation of Controls	.3	4
Stowage	.002	.1

TABLE 1

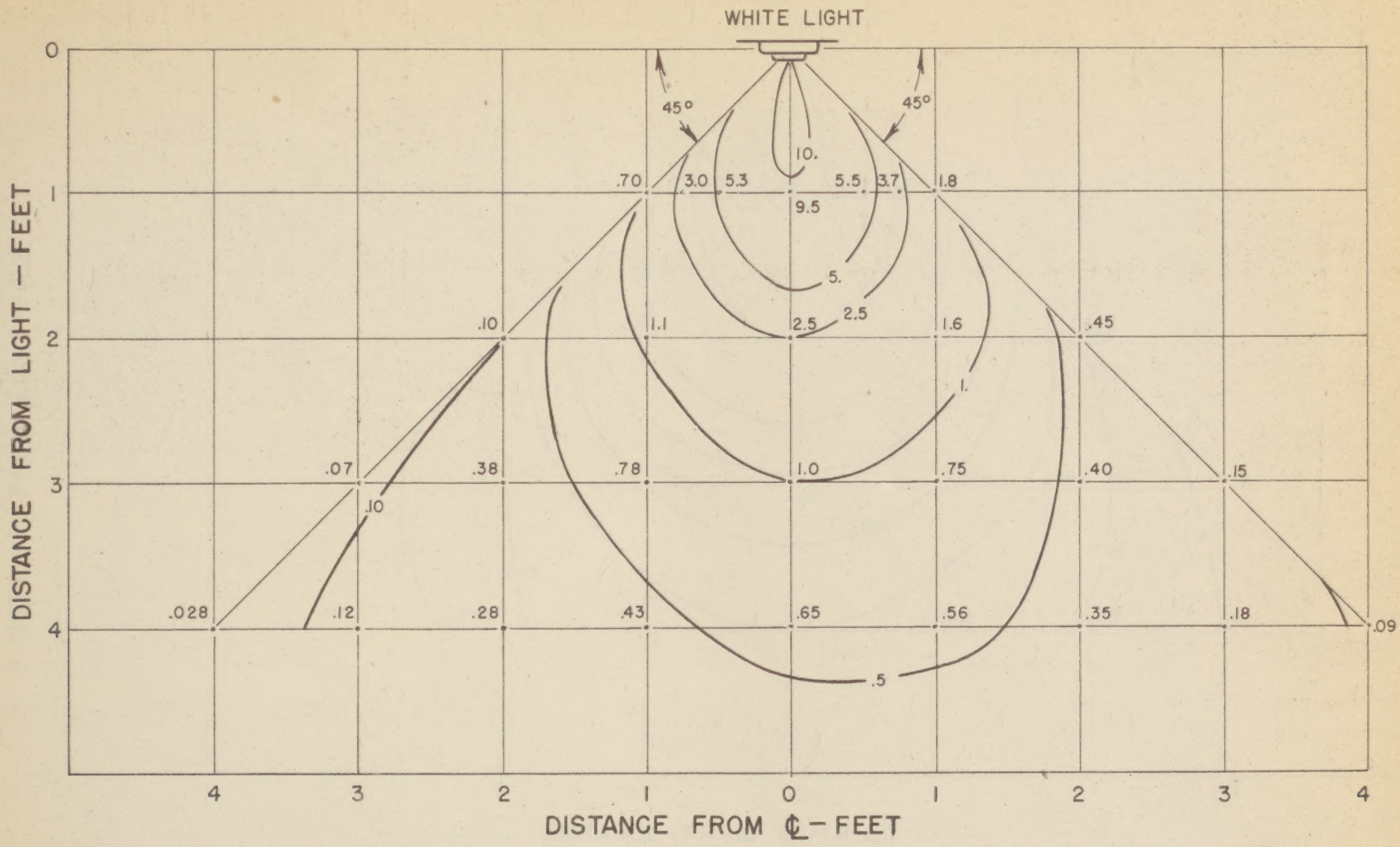
Incl. #2

GLARE RECOVERY TIME CURVES FOR MAP READING
AFTER 5 MIN. EXPOSURE TO OUTSIDE LIGHT



Incl. # 3

FIG. A ARMORED MEDICAL RESEARCH LAB.

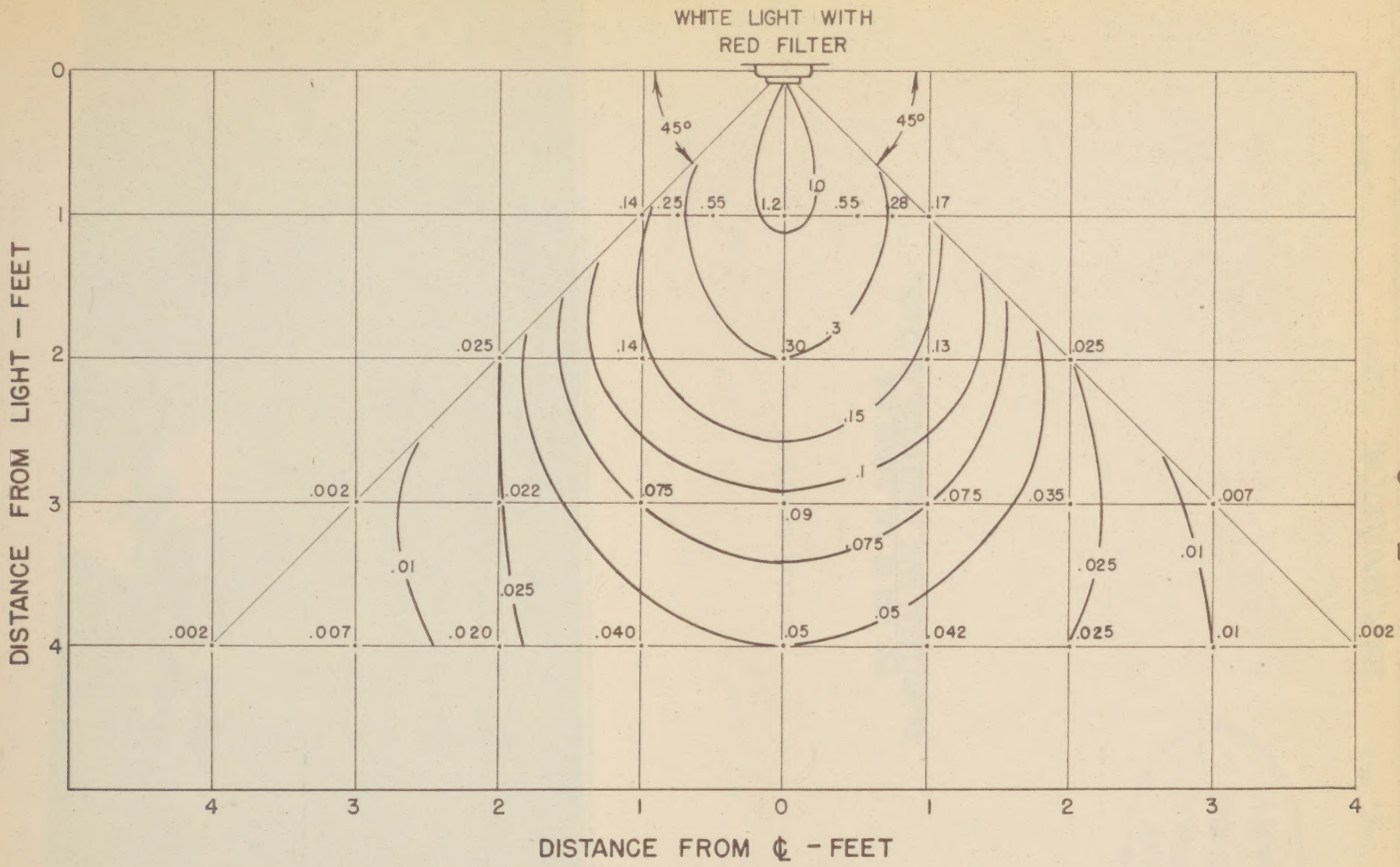


DISTRIBUTION OF WHITE LIGHT IN STANDARD TANK LIGHTING FIXTURE
(6 CANDLE POWER BULB)

FIG. B

FIG. B ARMORED MEDICAL RESEARCH LAB.

Incl. #3



DISTRIBUTION OF RED LIGHT IN STANDARD TANK LIGHTING FIXTURE

(6 CANDLE POWER BULB)

FIG. C

FIG. C ARMORED MEDICAL RESEARCH LAB.

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